‘NITREAT’ treatment for Anglian Water

nitrate removal plants being installed at six Anglian WTWs

The first full scale NITREAT system for removing nitrates from the water was installed for Thames Water at Sheafhouse WTW last year. The plant has already been in supply for more than six months, and has been proven to easily meet its performance guarantees, with regards to power consumption, waste production and chemical usage – all of which are considered to be extremely low in relation to conventional nitrate removal methods. Now, as part of an agreement with Biwater Treatment Ltd., ACWA Services are currently installing six of the nitrate removal plants at WTWs in various parts of the Anglian Water region. Detailed below is a description of the NITREAT System, and a synopsis of the performance observed at Sheafhouse WTW.

NITREAT system installed at Sheafhouse WTW for Thames Water *courtesy ACWA Services*

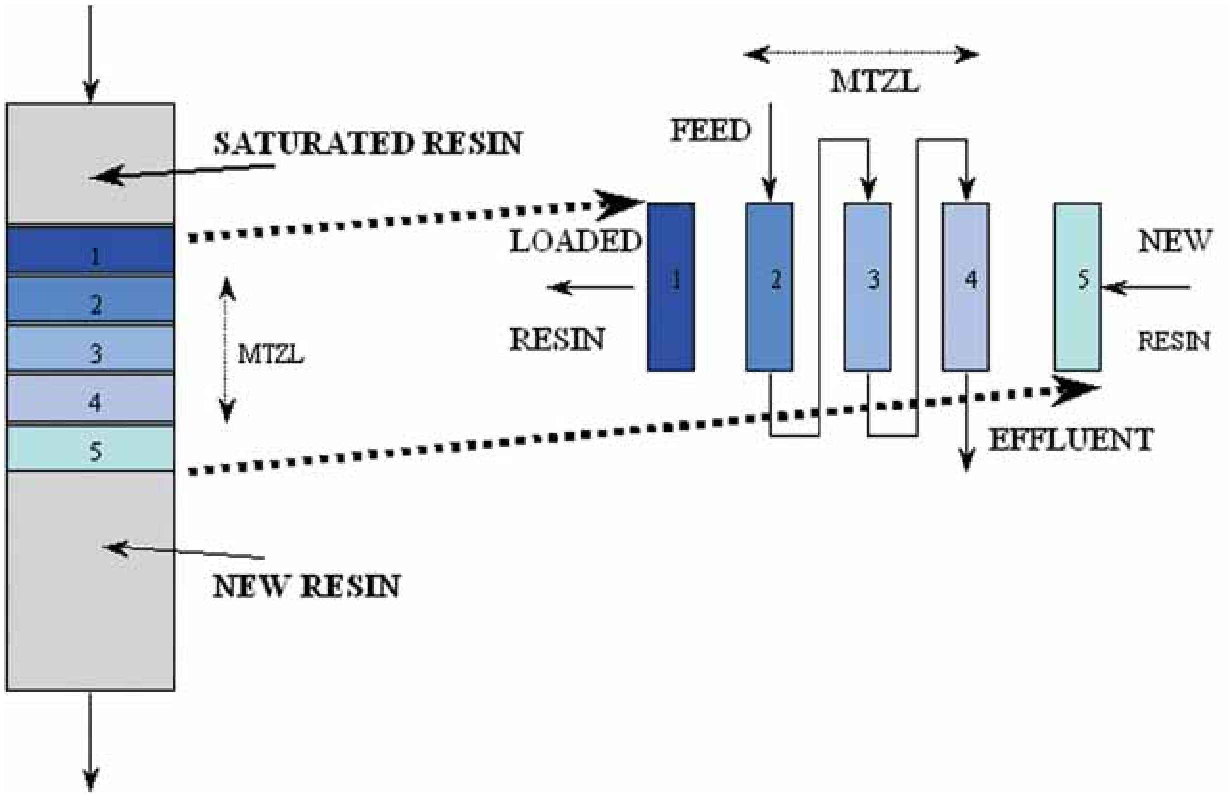
The system

The NITREAT System uses nitrate-selective resin to adsorb the nitrates in raw water. Traditionally, resin would be packed into a large fixed bed, and raw water allowed to flow through for a certain length of time (depending on nitrate levels) before the bed has to be taken off line for regeneration.

The NITREAT system is a true counter-current ion exchange system in which part of the ion exchange resin is continuously removed and regenerated, and then returned to the treatment system. Advantages of this system include elimination of long downtime for regeneration whilst maintaining consistent effluent characteristics.

Therefore, instead of packing a single large bed with resin (which may lead to ineffective utilisation of the resin in the bed), the resin is distributed into a series of smaller vessels, where the raw water is also more effectively distributed, to ensure a more complete utilisation of the resin.

In continuous processing, several smaller beds are arranged such that the total length of the series contact kinetically enough for adsorption of nitrates, and regeneration of resin to take place. In this system, vessels containing exhausted resin move out of the cascade at one end while regenerated beds come into the cascade at the other end.



Batch to continuous concept *courtesy ACWA Services*

The system is ‘true’ counter current, with respect to the configuration of the treatment vessels, which ensures that in the adsorption cycle, ‘fresh’resin is always being brought into the treatment zone, while exhausted resin goes out simultaneously, the regeneration stage ensures a progressive increase in brine strength, as it comes into contact with the exhausted resin. This is described later on, in more detail.

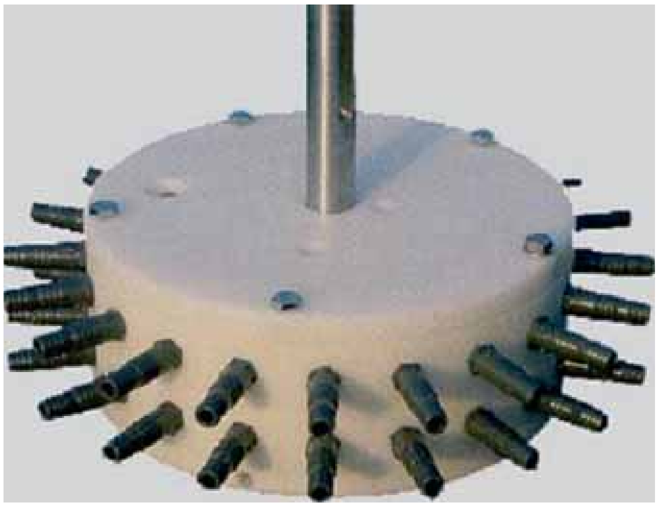
The NITREAT System is installed as an operator-free plant, with operator intervention required only as routine plant maintenance. The PLC responds instantaneously to fluctuations in nitrate levels and overall flow.

In most cases, it is only necessary to treat a portion of the total works flow for effective nitrate reduction. To achieve a final nitrate blend of under 50mg/l as NO_3 (Prescribed Concentration Value) for nitrates in drinking water, the PLC will automatically determine the proportion of the flow required to be treated, and then blend it back in with untreated flow, to achieve the final nitrate target. This calculation is based on the total flow, the achievable treated nitrate level, as determined by the resin, and the required final nitrate levels.

The process
The NITREAT system literally revolves around a central multiport distribution system, a patented multi-port valve, which acts as the heart of the process. All the flows (feed water, treated water, regeneration flows} feed to and from the multi-port valve.

The Multiport Valve is central to 20 resin containing vessels, arranged around it. Of the 20 vessels, 14 are in the adsorption zone at any one time, while the remaining six undergo a systematic regeneration cycle. The different vessels assume different roles in the treatment cycle, every time the internal disc in the valve rotates (termed ‘indexes’), as determined by the feed water characteristics.

Adsorption zone
70% of the total resin on the plant is in the adsorption zone at any one time. The resin contained in these vessels is of varying exhaustion degrees, ranging from a freshly regenerated vessel to a completely exhausted one at the end of its adsorption cycle. These vessels are connected in parallel, and the multiport valve allows for an even distribution of raw water to all 14 vessels.



Multiport valve *courtesy ACWA Services*

It is in this zone that the nitrates are adsorbed from the raw water onto the resin and replaced with chloride ions. It is worth noting that the resulting blended water would still have a chloride level well below the PCV of 250 mg/l.

Regeneration Sequence
The regeneration sequence comprises the remaining six vessels, divided into three consecutive, but independent zones:-

* ***Displacement Zone***
The vessel containing the most exhausted resin will enter the regeneration zone at the displacement zone. Here, an upward flow backwash (all the remaining vessels have downward flow), is undertaken in-situ in one vessel (of the six) without the need for an interruption in the treatment process.

The displacement zone effectively pushes potentially hard raw water out of the vessel, thereby preventing scaling problems from occurring on contact with regenerate (brine) solution. In the displacement zone, the resin is also flushed of any organics or solids which may have accumulated on the resin, although given the fine screening upstream of the vessels, this is deemed to be highly unlikely. Lastly, the upward flow in the displacement zone acts to prevent channelling from corrupting the performance of the resin bed, as the resin is fluidised and allowed to resettle.

* ***Brine Zone***

On exiting the displacement zone, the vessel enters the first step of the brine zone, where it is flushed with brine solution. The brine zone is made up of the next three vessels. These vessels are connected in series, to allow for the counter-flow regeneration of the resin. Here, the resin is exposed to a brine solution (formed from upstream rinse water and saturated brine solution).

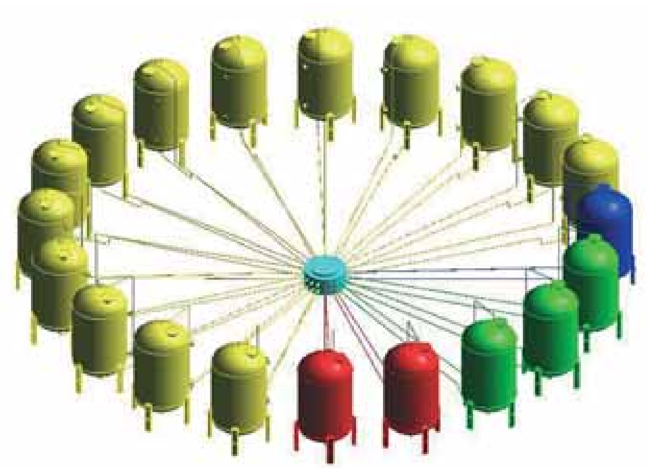
On the next index of the valve, the vessel, having already been exposed to a weakened brine solution, is then exposed to a slightly stronger one, and finally exposed to fresh brine solution.

This exposure effectively replaces the nitrates on the resin with chlorides, effectively allowing the resin to go back to the adsorption zone to adsorb more nitrates.

It is worth noting that, other than instrument wastes, the only source of waste from the plant will be exhausted brine solution, coming off the last of the three vessels in the brine zone. This will, - due to the configuration of the system - be directed via the multiport valve to waste.

***** ***Rinse Zone***

Before going back into the adsorption zone, the vessels have to be effectively flushed of the brine regenerant solution. Hence, the need for a two-step rinse zone, where softened treated water is used to flush out the remaining brine solution from the vessels. Two vessels are connected in series to each other and to the three brine zone vessels, thereby serving to re-use the softened water for brine dilution purposes, and contribute further to waste minimisation.



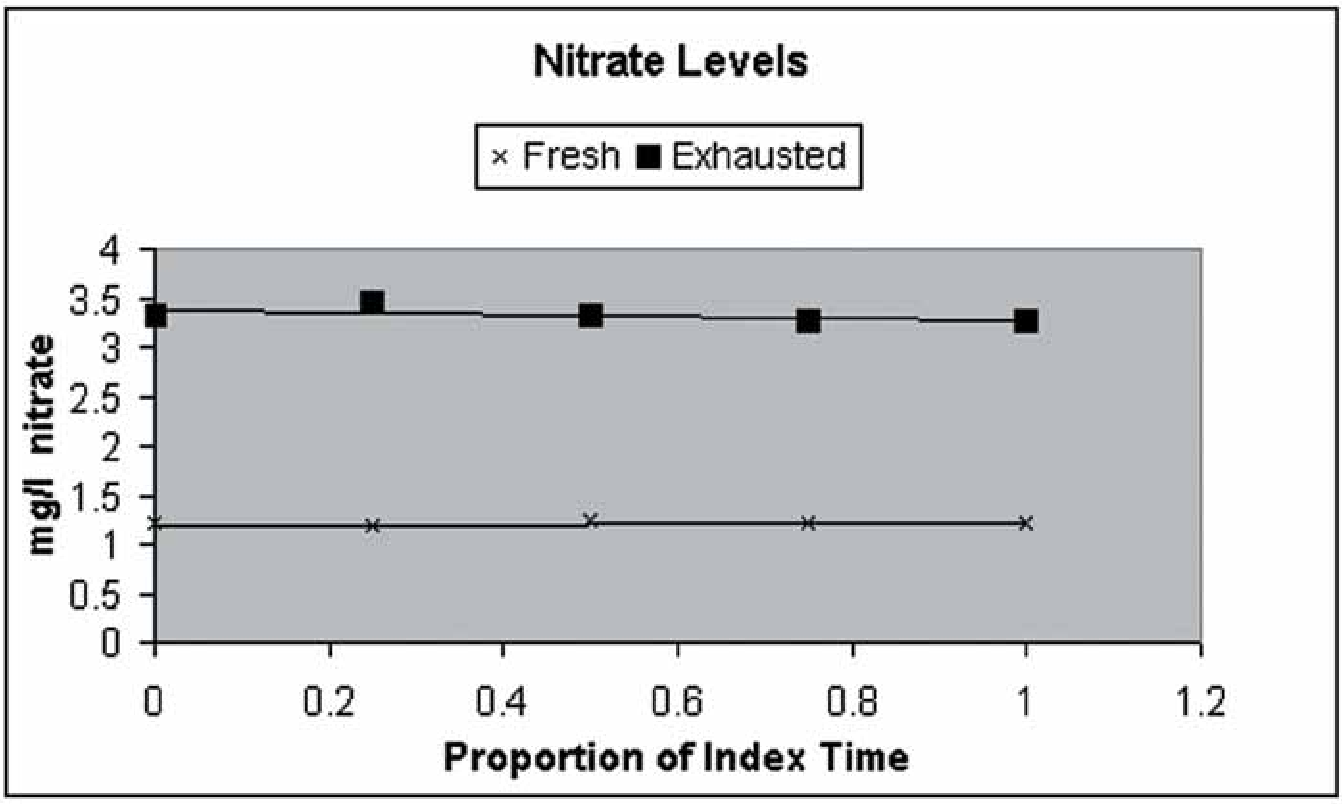
Process Zone distribution *courtesy ACWA Services*

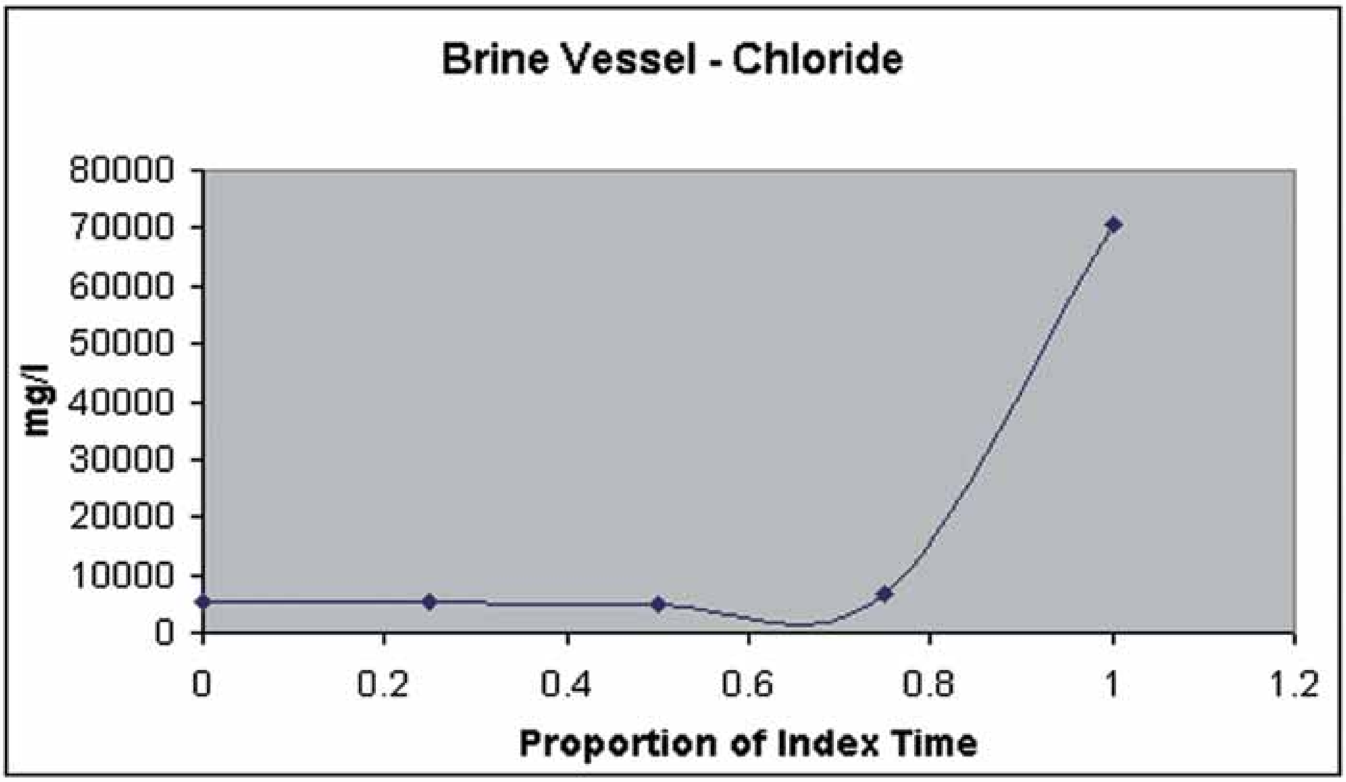
Result **from Sheafhouse**

The NITREAT Plant at Sheafhouse was set up to achieve a blended nitrate level of 42 mg/l as NO_3 irrespective of the raw water nitrate levels. Continuous monitoring of the nitrate levels was carried out using trending equipment and a dedicated nitrate monitor on the final blend. The target nitrate level was maintained and achieved consistently and permanently throughout the one month testing period, with the plant responding efficiently to fluctuations in overall flow and nitrate levels.

Analysis of individual process zones provided a helpful insight into the particular functioning of those zones. In brief, the analysis of the adsorption zone indicated that - as expected - the freshly regenerated vessel was producing nitrate levels near enough to zero, whereas the exhausted vessel was slightly higher, thereby justifying that the process parameters would be such that it would undergo regeneration at the correct time.

Looking at the above figure and at the overall nitrate levels coming off the adsorption vessels (2mg/l) it can be inferred that the adsorption zone would conform to a gradual increase in nitrate levels, indicating a gradual exhaustion of the resin.





The regeneration zone was running just as efficiently, as can be seen from the chloride break-through happening at the vessel in the last stage of the brine zone. As chloride replaces other anions adsorbed onto the resin, it cannot flow out of the vessel freely as it would replace nitrates, sulphates, carbonates and other anions on the resin bed. Once the result is re-saturated with chloride, and cannot adsorb any more, the chloride will not be effectively used and will flow out resin vessel.

From figure 5, it can be inferred that the quantity of brine used is optimised to ensure a complete regeneration of the brine, without wasting excess salt.The lack of conductivity in the treated line indicates that the rinse zone is effectively cleansing out the salt from the resin prior to going into the adsorption zone.

The plant is currently treating a total works flow of 34 l/s, equating to approximately 3 MLD, with a power draw of less that 19 kWh/day.

Conclusions

The overall performance of the plant was proven through one month of extensive sampling of the treated and final blended flows, and a continued 6-month operation period.

It can be concluded from the results and discussion above that the backwash and rinse flows are efficient. The brine flow is definitely sufficient, as despite the high nitrate content of the regenerant, the resin is completely regenerated prior to going back into supply, as can be seen from the quality of the outlet of the fresh vessel.

The salt usage, on the whole, was as per design figure guarantees, and given the design restrictions can be considered to be level with expectations.

The overall waste flow from the plant is extremely low. This is a major advantage of the NITREAT system, as this flow amounts to under 0.5% of the overall flow.

Lastly, the power consumption figures for the Sheafhouse NITREAT Plant indicated a power draw of approximately 0.15 kWh/m³/day.■

Note: *ACWA Services would like to thank Thames Water and Project manager, Adrian Jack, for releasing performance data for the above article.*